

Modeling of the Atmospheric Circulation in the Santa Barbara Channel

Eric D. Skyllingstad
College of Oceanic and Atmospheric Sciences
104 Ocean Admin. Bldg.
Oregon State University
Corvallis, OR 97331
Phone: (541) 737-5697 Fax: (541) 737-2540
Email: skylling@oce.orst.edu
Award #: N00014-98-0113

LONG-TERM GOALS

My long term goal is to better understand and predict the physics of small to mesoscale circulations in the coastal atmosphere using a combination of observations and model simulations.

OBJECTIVES

The objective of this project is to determine how local, coastal wind fields in the Santa Barbara Channel (SBC) region are affected by slowly varying synoptic weather conditions and diurnal heating. Because of differences in the winds across the SBC, horizontal shear and wind stress curl can vary rapidly and are highly sensitive to diurnal forcing. Conditions with NW flow outside Pt. Conception are frequently observed and create the largest gradients in horizontal winds across the SBC. I performed hindcast simulations for three different synoptic scenarios, each representing cases with steady, strong NW winds at the western end of the Santa Barbara Channel, but with variable winds at the eastern end. My goal was to understand how marine boundary layer depth, synoptic forcing, and diurnal heating affects the location and strength of the wind shear axis in cases with NW flow at Pt. Conception.

APPROACH

Simulations were performed using the Advanced Regional Prediction System (ARPS) mesoscale model developed at the University of Oklahoma. ARPS is a nonhydrostatic atmospheric mesoscale model that uses a terrain following coordinate system with both parameterized and explicit cloud physics. Three levels of nesting were employed in the simulations using a horizontal grid size of 60 x 60 and grid spacing of 36, 12, and 4 km, respectively. A stretched 32 level vertical grid was applied with grid spacing starting at 20 m for the finest resolution at the surface expanding to 450 m for the top grid levels. Initialization and boundary forcing for the model were prescribed using the National Center for Environmental Prediction (NCEP) 40 km Eta model analysis, which is available in 3 hour increments and archived at the National Center for Atmospheric Research. Hindcasts were performed over 12-hr periods with a 3 hour spin up prior to the beginning of the hindcast.

WORK COMPLETED

Wind field observations from buoy and land observations sites and a vertical radar profiler were used to identify cases with strong shear across the SBC. These cases were simulated using the model and then analyzed. Derived fields such as the boundary layer depth and horizontal momentum equation were

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 30 SEP 1999		2. REPORT TYPE		3. DATES COVERED 00-00-1999 to 00-00-1999	
4. TITLE AND SUBTITLE Modeling of the Atmospheric Circulation in the Santa Barbara Channel				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Oregon State University, College of Oceanic and Atmospheric Sciences, 104 Oceanography Admin Bldg, Corvallis, OR, 97331				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 5	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

used to help understand the dynamics of wind flow over the SBC region. A manuscript detailing this work is in preparation for journal submission.

RESULTS

Three cases were selected for analysis of NW flow events over the SBC region. The first case represents conditions with a strong off-shore high pressure, producing NW winds over most of the SBC. As shown by the profiler at Goleta in the eastern SBC (Fig. 1), this affects the circulation by causing deep, offshore flow and warm temperatures until ~10 UTC on July 2, 1998. Surface heating over the interior causes the flow to weaken during the daylight hours on July 2nd, however, the NW flow is reestablished aloft by 00 UTC on July 3rd. In the second case (July 17), the marine boundary layer is much shallower in comparison with July 2, so that coastal terrain influence is increased. This is shown in Fig. 1 by the southeasterly winds aloft and relatively weak flow near the surface. The temperature structure shows the overall decreased MBL depth and more pronounced effects of diurnal heating with deepening of the MBL during the daylight hours. Winds over much of the SBC with this scenario are weak throughout most of the day except in the western sections where the flow rounds Pt. Conception. Afternoon heating causes a modest increase in the circulation over the eastern SBC, but much less than on July 2.

The final case represents an intermediate MBL depth, blending the flow fields from cases 1 and 2. Winds in the late afternoon are strong from the west near the surface, but turn easterly after sunset. Winds aloft are consistently NW with a diurnal oscillation in strength. Because the MBL is deeper than on July 17, but still limited by terrain features, this case shows the greatest influence of diurnal heating and terrain effects. In particular, the MBL depth shows a strong relationship with the winds aloft, with deepening and weak NW winds during the morning and early afternoon, and a minimum in depth with strengthening NW winds at night and in the early morning. Although the MBL depth is relatively shallow in comparison with the July 2 case, the winds aloft exhibit a similar strengthening from the NW in the late afternoon. In contrast, the July 17 winds aloft are from the ESE and weaken over the prediction period.

Simulations of each case were performed for 24 hours starting on 00 UTC of July 2, July 17, and August 5 1998. Plots of the surface winds and MBL depth are shown in Fig. 2 at 4 UTC from each of the cases. These plots demonstrate the significant role the MBL depth has in setting both the wind speed in the SBC and the wind direction. With a deep MBL, as on July 2, the flow strength is maintained as winds round Pt. Conception and the flow only shows a modest expansion fan over the SBC and channel islands, with a significant flow across Pt. Conception as shown by offshore winds along the northern shore of the SBC. In contrast, the shallow MBL on July 17 shows a more significant change in the surface winds, especially in the far eastern SBC where the channel islands act as a second barrier to the flow, forcing a convergence zone at ~34 N. The MBL is deeper in the convergence zone, consistent with mass continuity. Air flow over Pt. Conception is still evident in this case as shown by the offshore vectors along the northern coast of the SBC. On August 5, a slight backing of the average wind direction toward a more westerly direction and weakening of the offshore flow prevents air flow from spilling over Pt. Conception in the western SBC as is evident on July 2 and 17.

By 12 UTC (Fig. 3), cooling of the land surface has caused a decrease in the onshore pressure gradient that was responsible for the westerly winds in the eastern SBC at 4 UTC. In the July 2 case, strong NW winds show only a slight turning in passing Pt. Conception, with winds in the lee of the Santa Ynez mountains appearing to be separated from the main flow. Both the July 17 and Aug 5 cases have a distinct shear line across the SBC; near the western end of the channel on July 17 and at the center on

August 5. All cases are consistent with the observations in showing relatively steady NW winds in the western SBC, while the eastern sections become calm or weak easterly. The depth of the MBL, however, does not agree with the observations on July 17, particularly in the afternoon when the MBL appears to have deepened to over ~200 m based on the profiler virtual temperature.

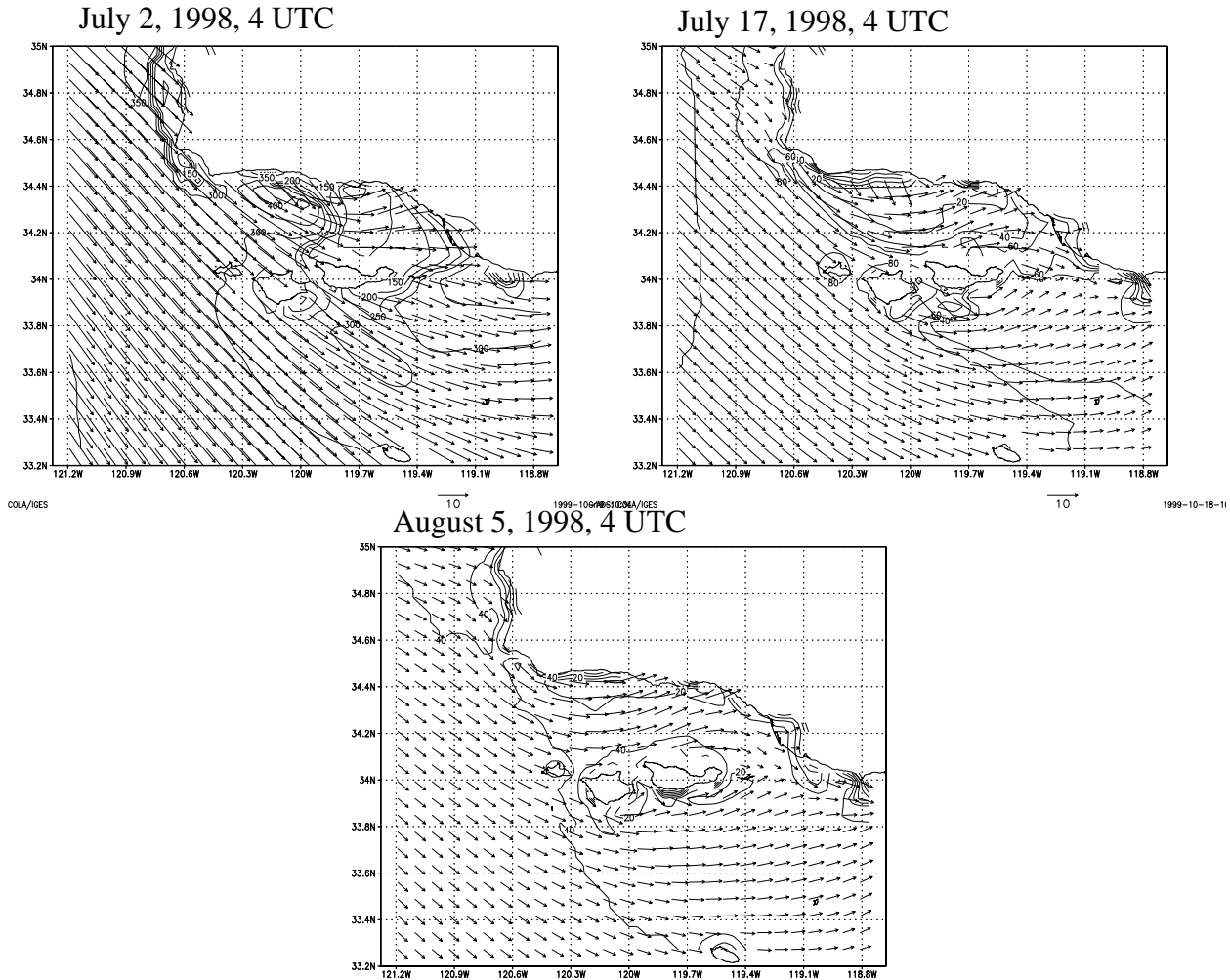


Figure 2. Simulated surface wind vectors (plotted every other grid point) and marine boundary layer depth from 4 UTC on July 2, July 17, and August 5, 1998.

The sensitivity of the shear zone to the strength and direction of the larger scale flow pattern is shown more clearly by comparing the 12 km resolution grid for the July 17 and August 5 cases (not shown). On July 17 the flow is ~3400 at 12 m s⁻¹ versus ~3150 at 8 ms⁻¹ on August 5. The difference in orientation on July 17 is sufficient to cause a flow separation in the lee of Pt. Conception as shown in Figure 3.

IMPACT/APPLICATIONS

Simulation results clearly show how the coastal mesoscale circulation is affected by terrain and diurnal heating and that numerical models are capable of predicting these circulations. Timely forecasts of the marine environment and changing ocean currents are possible by coupling mesoscale models with coastal ocean circulation models. Even without significant mesoscale data assimilation, the model was

able to produce a wind field that is quite similar to the buoy observations, although the timing of wind shifts and the absolute winds were not identical.

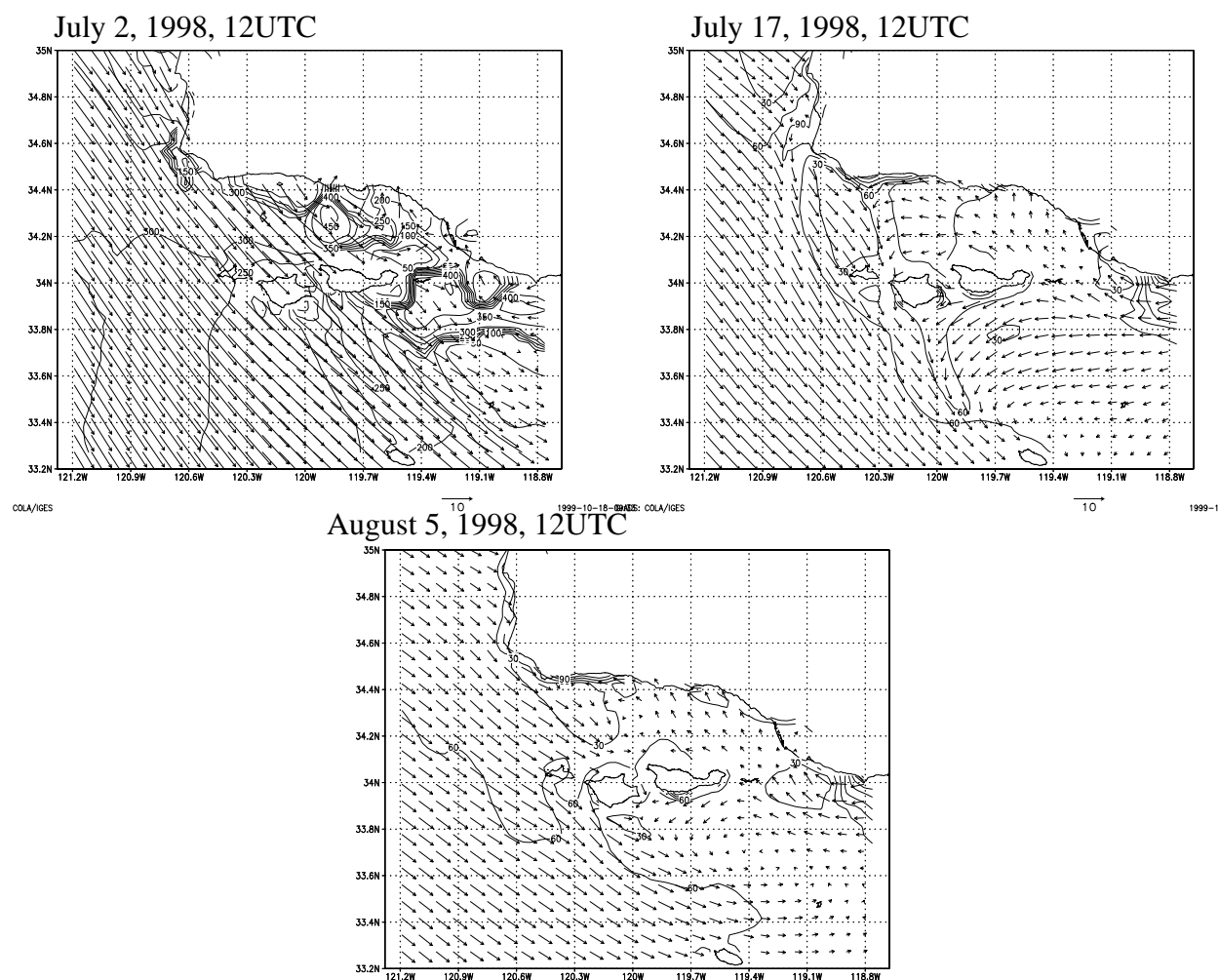


Figure 3. Same as Figure 2, except at 12 UTC.

TRANSITIONS

We are currently running the ARPS model in a real-time mode as part of the National Ocean Partnership Program. These real-time simulations are being archived and will be used as part of a hindcast using the Princeton Ocean Model of the circulation during the summer 1998 upwelling season.

RELATED PROJECTS

Our experience with the ARPS model has lead to a successful application to the Oregon Coast as part of the National Ocean Partnership Program. Collaboration is also ongoing with L. Mahrt in testing improved surface boundary layer parameterizations for the coastal zone.